

A REMARK ON THE METHOD OF ELECTRON BEAM ENERGY MEASUREMENT USING LASER LIGHT RESONANCE ABSORPTION.

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Abstract

The problem of measuring of the electron beam energy by help of the laser light interaction with the electrons is discussed. It is shown that the orthogonal orientation of the laser beam with respect to the electron one, proposed in the present Note, may allow to perform this measurement in accordance with the physical nature of a formation of an electron quantum levels in a magnetic field. In result, the final formula, that expresses the beam energy through the strength of a magnetic field and the energy of the laser photon, gets a transparent physical meaning and do contain a less number of parameters (what may lead to an increase of the precision of the measurement). Some other sequences from this proposal, like the change of the geometry of the experimental set-up and the necessity of a new additional detector to register the products of the Compton scattering for monitoring of the beam energy measurements, are discussed also.

1 Introduction.

An application of the resonance absorption (RA) of the light by electron [1] -[6] for the beam energy measurements was discussed in a number of talks given at different conferences [5], [6].

The idea of this method is based on the theoretical formula which was obtained for the first time in the framework of the non-relativistic quantum mechanics (see [7]) and latter on was generalized for the relativistic case basing upon the Dirac and the Klien-Gordon equations (see, for instance [8]). These formulae give the energy eigenvalues and the wave functions of the particle which moves in the homogeneous magnetic field. The analogous exact solutions were found also for a more complicated cases when a particle moves in

the combined field, composed of an electromagnetic and a homogeneous magnetic fields (Volkov solution, see also [9], [10]). Recently this study was continued by finding out the exact solution of the Dirac equation for a case of the superposition of a homogeneous magnetic field and a circularly polarized electromagnetic wave [4] with an account of the electron anomalous magnetic moment. It was shown that taking account of the electron anomalous magnetic moment removes the spin degeneracy of the energy levels.

According to the results of all these papers the particle which moves in a constant homogeneous magnetic field should have the quantized values of the energy, connected with its motion in the plane perpendicular to its velocity vector. In [1] and latter on in [4] it was proposed to use the transition from the lower levels of quantized transverse energy to the higher ones, caused by the laser photons absorption, for getting out the information about the initial electron beam energy (let us mention that in these papers the process of laser photon interaction with the beam electron was described within the Classical Electrodynamics framework).

In the present Note some new points of views on this measurement are proposed. First, the suggestion of a new orthogonal disposition of the laser beam with respect to the electron one is presented. Such a geometry of the measurement is different to the previously considered case, see [1] and [6], where the laser beam was supposed to be injected at a small angle to the electron beam direction (taken as z-axis). New proposal is based on the arguments which follow from the physical origin of the quantized levels of the electron energy in a magnetic field and would be discussed below in Section 2. The second point is connected with the usage of Quantum Electrodynamics (QED) approach for describing the laser photon interaction with the beam electron (see Section 3). The importance of the measurement of the Compton scattering (as the process that may happen when the experimental parameters would not meet the conditions necessary for RA) for monitoring of the beam energy measurement is discussed in the Sections 4 and 5.

2 The energy levels and the wave function of the electron in the static magnetic field.

Here (having in mind the aim of a further application for the beam energy measurements at ILC,¹ i.e. at the ultra-relativistic energies of electron) the solution of the Dirac equation would be used (taken from the widely used text book [11]), derived for a case of the electron motion in the homogeneous magnetic field ($\vec{B} = \text{rot} \vec{A}$), and with the choice of the Landau gauge for the 4-vector of the electromagnetic potential A_μ : $A_0 = A_x = A_z = 0$, $A_y = B_0 x$. Thus, $\vec{A} = B_0 x \vec{e}_y$, where \vec{e}_y is the unit vector along the y-axis, and $\vec{B} = (0, 0, B_z)$.

The energy of the electron p^0 , which is the fourth component of the electron 4-momentum vector $P_\mu = (p^0, p^x, p^y, p^z)$, is defined in this case by formula ([11]):

¹it seems to be very useful to perform first the analogous experiments at lower energies.

$$(p^0)^2 \equiv E_\lambda^2(n, p_z) = E_z^2 + E_{T,\lambda}^2(n), \quad (1)$$

where the first term

$$E_z^2 = m_e^2 c^4 + p_z^2 c^2 \quad (2)$$

is the square of the relativistic energy of a free electron that moves in a beam (taken as the z-axis). The second term

$$E_{T,\lambda}^2(n) = h \left(\frac{eB_0}{m_e} \right) (m_e c^2) (2n + 1 + 2\lambda) \quad (3)$$

is the square of the relativistic energy of the electron transversal motion, which depends on the strength of the magnetic field B_0 as well as on the spin projection “ λ ” on z-axis. Hence, the transversal energy of the electron has the quantized values, numerated by the main quantum number “n” ($n=0,1,2,3\dots$). Also m_e is the electron mass, e is its charge and h is the Plank constant, while $\frac{eB_0}{m_e} = \omega_c$ is the cyclotron frequency.

In what follows we shall use the expression for the difference of $E_{T,\lambda}^2(n)$ for the two neighboring values of energy levels with $n+1$ and n quantum numbers which stems from the formula (3):

$$\Delta E_{T,\lambda}^2 = E_{T,\lambda}^2(n+1) - E_{T,\lambda}^2(n) = 2h \left(\frac{eB_0}{m_e} \right) (m_e c^2) = 2h\omega_c (m_e c^2). \quad (4)$$

Now, let us note that in a case of the spin projection $\lambda = -\frac{1}{2}$ the ground state (i.e., $n=0$) would have, as it follows from (3), the value of the transversal energy been equal to zero: ²

$$E_{T,\lambda=-\frac{1}{2}}^2(0) = 0. \quad (5)$$

Here from comes an important fact (which would be used in what follows) that for the ground state with $n=0$ and the spin projection $\lambda = -\frac{1}{2}$ the expression for the *total energy of the electron in magnetic field* do coincides with *the energy of a free electron*:

$$E_{\lambda=-\frac{1}{2}}(n=0, p_z) = E_z = \sqrt{m_e^2 c^4 + p_z^2 c^2}. \quad (6)$$

In a complete correspondence with the formula (1), that demonstrates the independent entrance of E_z^2 and E_T^2 terms into the expression of the square of the total energy $E_{n,\lambda}^2$, ³ the wave functions of the Dirac equation, found as the exact solutions for the mentioned above different combinations of external magnetic and electric fields [1]- [11], also do factorize in two parts.

One part (an oscillator like solution) describes the motion in the plane transverse to the beam and along the x -axis (because the only nonzero component $A_y = B_0 x$ of the

²The next one level also having $n=0$, but with the spin projection $\lambda = +\frac{1}{2}$, would have the energy $E_{T,\lambda=+\frac{1}{2}}^2(0) = 2h\omega_c (m_e c^2)$, in accordance with formulae (3), (4).

³there is no interference term !

4-vector of the electromagnetic potential A_μ is defined by the x-coordinate). The another one, which has an exponential form, is connected with the free motions along the y- and z-axis (see [7] - [11]). For example, the solution, that corresponds to the formula (1), has a form ($\vec{r} = (x, y, z)$) [11] :

$$\psi(\vec{r}) = e^{i(p_y y + p_z z)} f(x), \quad (7)$$

where

$$f(x) = C e^{-\xi^2/2} H_n(\xi); \xi = \sqrt{eB_0}(x - p_y/eB_0). \quad (8)$$

Here C is the normalization constant and $H_n(\xi)$ is an Hermite polynomial which appear is a typical component of many solutions in a case of an oscillator type potentials. The exponents in $\psi(\vec{r})$ are the plane wave functions that do represent the typical solutions which describe a free motion of particles.

So, after we have discussed what type of motion is described by different components of the wave function, let us recall that in quantum mechanics the square of the wave function gives the value of the probability of finding out the particle at some point \vec{r} . Let us also add that from the statistics it is known that the probability of the process, that consists of the set of independent events, is defined as the product of the probabilities of independent events. As it is seen from the formula (7) this is just our case.

In this way the apparatus of quantum mechanics demonstrates that the motion of the electron in the homogeneous magnetic field does consists in reality of the sum of two independent motions. One motion, which is performed along the z-axis, is a free longitudinal motion and it is characterized by the momentum p^z . Another one is performed in the x-y plane, i.e. perpendicular to the beam axis, and does consists of the oscillator motion along the x-axis (this is a preferable choice of the coordinate system in the most of text books) and of a free motion along the y-axis with the momentum p^y .

After this discussion of the physical meaning of the formulae, used to describe the features of the quantized energy levels of the electron which moves in the homogeneous magnetic field, it is a time to consider a question of describing the interaction of the laser light with the beam electrons.

3 The laser photon interaction with the electron.

It is well known that in QED the lowest order (in e) amplitudes, i.e. the amplitudes for the $1 \rightarrow 2$ processes (like, for instance, a free electron transition into a free electron and a photon, i.e. $e \rightarrow \gamma + e$ process, as well as a photon transition into the electron positron pair $\gamma \rightarrow e^+ + e^-$) are forbidden due to the relativistic kinematics (see, for example, [11]-[13]). To this reason in QED the lowest order amplitude does corresponds to the next to leading (i.e. e^2 order) diagrams that describe a $2 \rightarrow 2$ transitions like $\gamma + e \rightarrow \gamma + e$ (Compton scattering). This result is in agreement with the common sense statement that the electron, been forced to change his speed (accelerated/deaccelerated) by some external influence, should radiate the energy. In QED it means an emission of photons.

In a correspondence with this statement the 4-momentum conservation law for the Compton process of the photon (with the 4-momentum k_1) scattering off the electron

(with the 4- momentum p_1) looks, in a general case, like (k_2 and p_2 are the final state momenta of the photon and the electron):

$$p_1 + k_1 = p_2 + k_2. \quad (9)$$

If we shall pass to the components of the 4-momentum: $k^\mu = (k^0, \vec{k})$; $\vec{k} = (\vec{k}_T, k^z)$, then the equation (9) may be presented as a set of the independent conservation laws for each component separately:

for the energy,

$$p_1^0 + k_1^0 = p_2^0 + k_2^0, \quad (10)$$

for the z-projection:

$$p_1^z + k_1^z = p_2^z + k_2^z, \quad (11)$$

and for the transversal one

$$p_1^T + k_1^T = p_2^T + k_2^T. \quad (12)$$

Thus, if the laser photon would have some small angle θ to the electron beam, as it was considered in [1] and [6] (in such a case the k_1^z component of the photon momentum would dominate over his transverse one k_1^T), then the z-component of the electron would change, in general case, from p_1^z to some p_2^z due to the conservation law of the z-component of 4- momentum.

Independently from the z-component, the transversal component of electron may also change after the interaction. There are two possible cases, which may be realized in the framework of QED.

The first one, most simple, may be realized when the \vec{k}_1^T contribution to the electron transversal motion would not match the difference (4) of two quantized electron energy levels in a magnetic field. In this case, according to QED a pure Compton scattering would take a place.

The second one may happen when the value of $|\vec{k}_1^T|$ should match the equation(4). In this case, keeping in mind what was written before about the independent conservation of z- and transverse components of the total 4-momentum of electron-photon system, we shall have the final state consisting of :

. the photon, radiated due to changing of the electron momentum z-component (and in accordance with (11)),

. and the electron, which $|\vec{p}_2^T|$ should be defined in this case by formula (3) for the (n+1)-th , or even higher level, if it was at the n-th orbit in the initial state.

Hence, in both cases, *even if the resonance condition would be fulfilled and the transverse component k_1^T would exactly coincide with the energy necessary for moving from the lower orbit to the higher one* (i.e. the equality $\vec{p}_2^T = \vec{p}_1^T + \vec{k}_1^T$ would be fulfilled for the *independent(!) motion in the transverse plane*), *the changing of the independent z-component*

of the electron momentum would lead to the radiation from the electron. In QED it is an emission of the photon via the e^2 order Compton process.⁴

In other words, according to QED, in a case, when the laser beam would have a small angle θ with respect to the electron beam, the Compton process (with or without moving of an electron from the lower orbit to a higher one) would take place and the emission of the photon would happen. In such a case the whole situation becomes more complicated for the theoretical description.⁵

A possible simple way to avoid these problems and to use the theoretical prediction about the existence of the quantized energy levels (of the transverse motion of the particle in the magnetic field) for the electron beam measurement is given below. It is based on a special choice of the angle between the laser and the electron beams, mentioned already in the Introduction.

4 What laser photon beam orientation meets better the physics of electron motion in magnetic field?

The physical picture of the electron motion in the static magnetic field as been a sum of two independent motions (what was discussed in the previous Sections) as well as the 4-momentum conservation equations written above, do prompt (if not to say, dictate) an easy way to prepare the initial state to use the possibilities connected with existing of the quantized energy levels of a particle in the magnetic field. This possibility is based on the proper choice of the relative geometrical orientation of the laser and the electron beams.

Indeed, if we shall choose the laser beam to be orthogonal to the electron one, i.e. shall consider a case when $k_1^z = 0$ in equation (11), then the collision of the laser photon with the electron would not effect the z-component of the electron momentum at all.

If also, in addition to the orthogonal angle orientation, we shall adjust the laser photons energy (and the magnetic field strength B_0)⁶ to be equal to the difference of the two lowest quantized levels of energy, connected with the transversal motion of the electron in a magnetic field and defined by formula (4), then the laser photon would be absorbed.⁷ In this case the whole initial photon energy, been prepared as of the transversal nature only, would transform into the energy of a its circular motion, but on a higher then previous one orbit in the plane transverse to electron beam. Therefore, in a case of the proposed

⁴which would have the energy and angular distributions similar to those that appear in a case of laser back scattered photons, described in [14]. It should be mentioned that the estimates of the laser photon energy, or, of the wave length, appropriate for the RA effect at TESLA energies [6], give the value about of $\lambda_{las} = 10\mu m$. This number is quite comparative with the wave length of the laser $\lambda_{las} = 1\mu m$, planned to produce the backscattered laser photon beam for photon-photon collisions [14].

⁵there are no complete calculations found in the literature that may describe this general case up to the end.

⁶better to say to adjust the choice of the laser to get the most suitable wave length and then to tune the value of the magnetic field strength B_0 . We shall return to this question in the next Section.

⁷let us mention that in the framework of QED, the process of photon absorption goes on practically immediately.

orthogonal orientation and the properly tuned value of the magnetic field strength B_0 in a way to have the difference of two energy levels of the electron in accordance with the energy of the laser photons *there would be no any phase space left for the production of an additional photon in the final state!*

In this special case of $k_1^z = 0$ and when also the laser energy would fit the difference of two E_T for some n and $n+1$ levels, the formula (11) shall take a very simple form:

$$p_1^z = p_2^z. \quad (13)$$

(This equation may be treated also as one of the conditions of RA effect.)

The energy conservation law in the such a case of $\theta_{laser} = 90^\circ$ should look like

$$p_1^0 + k_1^0 = p_2^0, \quad (14)$$

where, due to our choice of the laser photon momentum 4-vector in a form $k_1^\mu = (k_1^0, \vec{k}_1)$; $\vec{k}_1 = (k_{1T}, 0)$, the final state electron transverse momentum p_2^T would be defined by the the equation

$$\vec{p}_1^T + \vec{k}_1^T = \vec{p}_2^T, \quad (15)$$

as the sum of the initial electron transverse momentum \vec{p}_1^T and the laser photon transverse vector \vec{k}_1^T which modulus is equal to the energy of the absorbed photon⁸.

The 4-component equation (9) would take in such a case the following form:

$$p_1 + k_1 = p_2. \quad (16)$$

Note that for the considered here process the right hand side of equation (14) may be represented like

$$p_2^0 = \sqrt{E_\lambda^2(n+1, p_2^z)} \quad (17)$$

(where the value $E_\lambda^2(n+1, p_2^z)$ is defined by formula (1)) if the beam electron initially was “on the n -th orbit”.

Taking the square of equation (14) and with an account of formula (1) one comes to the equation for a non spin-flip case

$$E_\lambda^2(n, p_1^z) + 2k_1^0 E_\lambda(n, p_1^z) + (k_1^0)^2 = E_\lambda^2(n+1, p_2^z), \quad (18)$$

which can be rewritten (in what follows we shall use the notation $k_1^0 = E_{las}^\gamma$) like

$$2E_{las}^\gamma E_\lambda(n, p_1^z) + (E_{las}^\gamma)^2 = E_\lambda^2(n+1, p_2^z) - E_\lambda^2(n, p_1^z). \quad (19)$$

This is a general form of equation (14) for any values of p_1^z and p_2^z .

Now, if we shall take into account the p^z conservation law in a form (13), that corresponds only to the discussed above laser to beam orthogonal orientation, then the right hand side of (19) would contain the expressions of the total energies of electrons in the magnetic field for a case of equal values of p^z components ($p_1^z = p_2^z$):

⁸i.e., $k_1^0 = |\vec{k}_{1T}|$ due to the relation $k_1^0 = |\vec{k}_1|$, which is valid for the massless photon.

$$2E_{las}^\gamma E_\lambda(n, p_1^z) + (E_{las}^\gamma)^2 = E_\lambda^2(n+1, p_1^z) - E_\lambda^2(n, p_1^z). \quad (20)$$

From formula (1)-(3) it is clear that the longitudinal contributions E_z^2 would cancel in the right hand side of (20)⁹ and only the difference of the transverse energies $E_{T,\lambda}^2(n)$ would remain there:

$$E_\lambda^2(n+1, p_1^z) - E_\lambda^2(n, p_1^z) = E_{T,\lambda}^2(n+1) - E_{T,\lambda}^2(n). \quad (21)$$

The expression for this difference was already given by formula (4). So formula (20) could be presented in a form

$$2E_{las}^\gamma E_\lambda(n, p_1^z) + (E_{las}^\gamma)^2 = \Delta E_{T,\lambda}^2, \quad (22)$$

which does not contain any more the dependence on the beam energy in the right hand side of the equation. In such a case it is convenient to present (22) as an equation which includes the dependence on the electron beam energy (see (1)) only in the left hand side:

$$E_\lambda(n, p_1^z) = \frac{\Delta E_{T,\lambda}^2 - (E_{las}^\gamma)^2}{2E_{las}^\gamma}. \quad (23)$$

Let us consider now the case of the non spin-flip transition from the ground state $n=0$ to the state with $n=1$ (we shall choose a case when both states have $\lambda = -\frac{1}{2}$), then the formula (23) (written as $E_{\lambda=-\frac{1}{2}}(n=0, p_z) = E_z = \sqrt{m_e^2 c^4 + p_z^2 c^2} = E_{beam}$) gives, due to (6), the following expression for the beam energy E_{beam}

$$E_{beam} = \frac{\Delta E_{T,\lambda=-\frac{1}{2}}^2 - (E_{las}^\gamma)^2}{2E_{las}^\gamma}. \quad (24)$$

Keeping in mind that according to formula (4) for the non spin-flip case, i.e. when the value of λ does not change in the process of the beam electron interaction with the laser photon, we have $\Delta E_{T,\lambda}^2 = 2h\omega_c(m_e c^2) = 2h(eB_0/m_e)(m_e c^2)$, we come to a very simple final formula

$$E_{beam} = \frac{2h(\frac{eB_0}{m_e})(m_e c^2) - (E_{las}^\gamma)^2}{2E_{las}^\gamma}. \quad (25)$$

The last equation does express the value of the beam energy through those values of the magnetic field strength B_0 and of the laser photon energy E_{las}^γ , which were tuned to provide the conditions for the laser photon energy to be equal to the difference of two neighboring quantum energy levels in a case of the orthogonal relative orientation of the laser to the electron beams.

It is natural that the error of the measurement of the electron beam energy ΔE_{beam} should be defined in this case by two errors only :

⁹here the advantage of the orthogonal beams orientations, accumulated in equation (13), come into a play!

- . the error of the magnetic field strength ΔB_0 measurement, and by
- . the error of the measurement of the laser photon energy ΔE_{las}^γ .

To summarize shortly it is possible to say that in a case when the following conditions would be fulfilled:

* the angle between the laser and the electron beams would be chosen to be $\theta = 90^\circ$, (i.e. $\cos\theta = 0$),

** the magnetic field strength B_0 and the laser photon energy E_{las}^γ would be tuned to provide the conditions for the laser energy to be equal to the difference of two neighboring quantum energy levels of the electron in a homogeneous magnetic field ,

then the photon may be absorbed by the quantum system of the quantized electron levels in a homogeneous magnetic field and

the laser photon collision with the beam electron may lead only to a change of the orbit number of the transverse motion of the electron. No changes of the longitudinal (i.e., of z-) component of the electron momentum would happen. It means that no any additional radiation (like that one which take place in the Compton scattering process) would have sufficient phase space to appear.

5 How it may look from the experimentalist point of view.

There are some points have to be discussed in a connection with a possible planning of the measurements if they should be done in the context of the described above picture of the laser photon interaction with the beam electron.

The obvious question needed to be asked for such a planning would be about the choice of the laser energy (i.e., the wave length). The answer can be easily found from the solution of the quadratic equation (25) for the E_{las}^γ . In a case of $n=0$ and $\lambda = -\frac{1}{2}$ we come to the formula ¹⁰

$$E_{las}^\gamma = E_{beam} \left(\sqrt{1 + \frac{2h(\frac{eB_0}{m_e})(m_e c^2)}{E_{beam}^2}} - 1 \right) = E_{beam} \left(\sqrt{1 + \frac{\Delta E_{T,\lambda}^2}{E_{beam}^2}} - 1 \right), \quad (26)$$

which expresses E_{las}^γ through the value of the beam energy E_{beam} and the strength of the

¹⁰in a case when $\Delta E_{T,\lambda}^2/E_{beam}^2 < 10^{-2}$ this formulae simplifies and turns into a very easy relation $E_{las}^\gamma = \Delta E_{T,\lambda}^2/2E_{beam}$. It is rather curious to note that its inversion gives a more strait forward (but a bit approximate) expression for the electron beam energy $E_{beam} = \Delta E_{T,\lambda}^2/2E_{las}^\gamma$, which, by the way, may be obtained from the equation(23) if one shall neglect the term $(E_{las}^\gamma)^2$ in its numerator. The similar approximation was used in [1], and [6] for a case of $\cos\theta \neq 0$.

magnetic field B_0 . So, with the help of this formula one can find out (for a chosen value of E_{beam} and an expected value of B_0) what kind of a laser does have the wave length that corresponds to the energy defined by formula (27).

The next important sequence for planning of the experiment is the need to pass to a new geometry for the experimental set-up for such measuring of dropping of the laser light intensity due to the photon absorption. It is evident that the detector (D), proposed to measure the decrease of the laser light intensity after its interaction with the electron beam [6], and the laser should be placed on the same line, perpendicular to the electron beam. Such a geometrical disposition of the experimental setup looks very different to what was discussed in [1]- [6], where it was proposed that the line which connects the laser and the detector (D) would have a small angle θ to the electron beam line.

This changing of the position of the detector D may be important from the experimental point of view. Really, in principle, there is a non zero probability that the electron, which was forced by the laser light to move to a higher orbit, would emit a photon and then return after some time back onto the ground state orbit. Here we have a direct analogy with the radiative transition from higher to lower orbits in atoms. Fortunately, in the case, proposed in the present Note, the electron, been moved onto any the higher orbit, would keep, as it was discussed in the previous Sections, the same value of the initial longitudinal momentum p_1^z (as it was discussed in the previous Sections), i.e., it shall continue to move with the same speed, practically equal to the speed of light. Hence, if the photon emission would happen at some moment, defined by the lifetime of the “n+1-th” excitation level, nevertheless, this photon have no chances to hit the detector D, because during this even small time the electron, that was pushed to the “n+1-th” orbit, would fly already away from the position of the “laser-detector D” perpendicular line (to the electron beam line). To this reason the proposed here perpendicular orientation of the laser to electron beam is a preferable one as it is more safe from the view point of the possibility that the secondary radiative photon emission may reach the detector D.

Up to now we were discussing the aspects connected with the case of the resonance absorption within the situation of a new orthogonal disposition of both beams. Now let us turn to the situation when the energy of the laser photon would not fit to the the value of energy splitting between the main $n=0$ and one of the next to the ground states levels.

As it was already discussed in the previous Sections, in a case when the resonance condition (25) would not be fulfilled (most probably, due to some variation of the electron beam energy) then according to QED the Compton process of $\gamma + e \rightarrow \gamma + e$ scattering would take place.

The appearance of the Compton scattering products, i.e. of the final state photon and electron (with $p_2^z \neq p_1^z$) may be used as the signal of a dropout from the resonance condition (25). Therefore, the addition of experimental equipment, supposed for beam energy measurement, by a new detector which may identify the electrons and photons, produced in the Compton scattering, may be very helpful. It may be an electromagnetic calorimeter with the appropriate granulation for the registration of the photons and for defining of their position, accompanied by some electron tracker.¹¹

¹¹Really, if there would be only one detector D for measuring of the decrease of the laser light, caused by

It should be mentioned also that if we shall suppose that the effects of the electron beam energy variation would not be so large, then it would not be so difficult to calculate the angle and energy distributions of the scattered photons and electrons which would be characteristic for the such possible variations of the electron beam energy in both directions from the position of the resonance value.

Thus, it may happen so that the control over the Compton process (by a comparison of the observed experimental distributions of the photon and the electron parameters with those predicted by QED) would turn out to be a useful guide for adjusting the magnetic field strength B_0 during the beam energy measurement. In such a case the measuring of the characteristics of the Compton scattering within the region of parameters, close to the resonance position, may be used for the on-line tuning of the magnetic field strength to those values which would be an adequate to keep the resonance condition. The detailed study of this possibility would be a subject of the following publications.

6 Summary.

It is shown that the orthogonal orientation of the laser photon beam with respect to the electron beam allows to bring the idea of the use of the theoretical prediction about the existence of electron quantum levels (in the presence of the homogeneous magnetic field) in the correspondence with the physical origin of these resonance levels.

In result, the formulae that describe a process of a possible absorption of the laser light by the transverse degrees of electron motion in the constant magnetic field become much simpler because in this case the absorption process does not interfere with the longitudinal motion along the beam direction. Due to this no additional radiation would appear in a case when the laser photon energy would fit the value of the energy splitting of two electron levels in the magnetic field (i.e. in a case of fulfilling the resonance condition). In result, the physical picture of the process of measuring the electron beam energy by measuring the drop of the laser light intensity in the absorption process becomes more transparent. This new relative orientation of two beams means also passing to another geometry for experimental tools set-up.

In the opposite case when the energy of the laser photon would not be equal to the difference of two electron energy levels (in magnetic field) the Compton scattering process would take place. The characteristics of the scattered electron and photon (angles and energies) may be measured (it may require to enlarge the experimental equipment by the additional electromagnetic calorimeter and the tracker) and then used for an on-line monitoring of the process of tuning the magnetic field to keep the resonance photon absorption condition (25) for the electron beam energy measurement.

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the resonance absorption, then we would not have a full information about the origin of such a variation, because it may happen also, for instance, due to the variation of the beam density.

References

- [1] I.A.Gilinski and K.A.Ryasantsev; Izv.Vuz. Radiophysics, **5** (1964) 838;
- [2] V.G.Bagrov and V.R.Khalilov; Izv.Vuz.Physics, **2** (1968) 37;
- [3] V.P.Milant'ev; Phys.Uspekhi, **40**, 1 (1971) 1; Uspekhi Fiz.Nauk, **167**, 1 (1997) 37;
- [4] R.A.Melikian and D.P.Barber, DESY report 98-015 (1998), hep-ph/9903007;
- [5] R.A.Melikian and D.P.Barber Proc. 13 Intern. Symposium on High Energy Spin Physics (Spin98), p. 495,Protvino, Russia, 8-12 Sept. 1998;
- [6] D.P.Barber and R.A..Melikian, Procc. of EPAC 2000, Vienna, Austria,p.996, <http://accelconf.web.cern.ch/accelconf/e00/PAPERS/MOP1B01.pdf>;
- [7] L.D.Landau and E.M.Lifshitz, "Quantum Mechanics", Nauka, Moscow, 1989.
- [8] A.A.Sokolov, I.M.Ternov and C.W.Kilmister "Radiation from Relativistic Electrons", American Institute of Physics(translation series), 1986 ; Naika, Moscow,1983.
- [9] P.J.Redmond, J.Math.Phys. **6** (1965) 1163;
- [10] J.Bergou, F.Ehlotzky, Phys.Rev **A27** (1983) 2291;
- [11] A.I.Akhiezer,V.B.Berestetskii "Quantum Electrodynamics, Fizmatgiz, Moscow , 1957. Interscience Publishes, New York, 1965;
- [12] V.B.Berestetskii, E.M.Lifshitz, L.P.Pitaevskii, "Quantum Electrodynamics", Nauka, Moscow, 1980; Pergamon press (1982),Addison Wesley Publ.,1971;
- [13] N.N.Bogoliubov, D.V.Shirkov "Introduction to the Theory of Quantized Fields", Fizmatgiz, Moscow , 1957; A Wiley-Interscience Publication; John Wiley and Sons, New York,1979;
- [14] TESLA.Technical Design Report <http://tesla.desy.de/tdr/> Chapter IV, The Photon Collider at TESLA <http://tesla.desy.de/tdr/PartVI/append.html> .